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OPTIMIZING MARINE CORPS MAINTENANCE PERSONNEL CONVERSION TO THE JOINT STRIKE FIGHTER

by

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The United States Marine Corps (USMC) is replacing its fixed wing fighter and attack aircraft with the new F-35B Joint Strike Fighter (JSF). The Marines' F-35B will replace three aging aircraft: F/A-18 A+/C/D Hornet, AV-8B Harrier, and EA-6B Prowler. With the retirement of these aircraft, their associated military occupational specialties will become obsolete. The F-35B is an expensive asset, and once it is delivered the USMC wants it to be immediately operational. One of the challenges is how to prescribe the right types of maintenance personnel for accession and conversion to the JSF community as it gets established, while maintaining adequate quantities of experienced personnel in the legacy communities. This thesis develops an Integer Linear Program (ILP) that prescribes the number of maintenance personnel for monthly transition and accession into the new JSF community. The ILP reveals possible shortage or overfill of manning for each new squadron, taking into consideration the rank and years of service of available personnel for each month of an 11-year planning horizon. Using realistic data, we demonstrate the use of the ILP under different levels of accession and allowed transition for four types of maintenance personnel.

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OPTIMIZING MARINE CORPS MAINTENANCE PERSONNEL CONVERSION TO THE JOINT STRIKE FIGHTER

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ABSTRACT

The United States Marine Corps (USMC) is replacing its fixed wing fighter and attack aircraft with the new F-35B Joint Strike Fighter (JSF). The Marines' F-35B will replace three aging aircraft: F/A-18 A+/C/D Hornet, AV-8B Harrier, and EA-6B Prowler. With the retirement of these aircraft, their associated military occupational specialties will become obsolete. The F-35B is an expensive asset, and once it is delivered the USMC wants it to be immediately operational. One of the challenges is how to prescribe the right types of maintenance personnel for accession and conversion to the JSF community as it gets established, while maintaining adequate quantities of experienced personnel in the legacy communities. This thesis develops an Integer Linear Program (ILP) that prescribes the number of maintenance personnel for monthly transition and accession into the new JSF community. The ILP reveals possible shortage or overfill of manning for each new squadron, taking into consideration the rank and years of service of available personnel for each month of an 11-year planning horizon. Using realistic data, we demonstrate the use of the ILP under different levels of accession and allowed transition for four types of maintenance personnel.

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DISCLAIMER

The reader is cautioned that the computer programs presented in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logical errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABM	Agent Based Modeling
ALIS	Autonomic Logistic Information System
CALF	Common Affordable Lightweight Fighter
COMNAVAIRFOR	Commander Naval Air Force
CSV	Comma Separated Value
DoD	Department Of Defense
FRS	Fleet Replacement Squadron
FW	Fighter Wing
FY	Fiscal Year
GAMS	General Algebra Modeling System
GUI	Graphical User Interface
IETM	Interactive Electronic Tech Manual
ILP	Integer Linear Program
IMA	intermediate Maintenance Activity
IOC	Initial Operation Capability
JAST	Joint Advanced Strike Technology
JDIS	Joint Distributed Information System
JSF	Joint Strike Fighter
MALS	Marine Aviation Logistic Squadrons
MCMCAM	Marine Corps Maintenance Conversion Analysis Model
MOS	Military Occupational Specialty
MXG	Maintenance Group
NAMP	Naval Aviation Maintenance Program
NAS	Naval Air Station
RFO	Ready For Operation
STOVL	Short Take-off and Vertical Landing
T/O	Table of Organization
USMC	United States Marine Corps
YOS	Years of Service

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EXECUTIVE SUMMARY

The United States Marine Corps (USMC) is facing the challenge of transitioning from legacy fixed-wing aircraft to the new Joint Strike Fighter (JSF) aircraft. The USMC version of the JSF, the F-35B, will replace three aging aircraft: F/A-18 A+/C/D Hornet, AV-8B Harrier, and EA-6B Prowler. The F-35B is an expensive asset so, once it is delivered, the USMC wants it to be immediately operational. This requires a detailed plan to man and train personnel during the JSF integration while maintaining adequate personnel in the legacy aircraft communities until they are phased out. The challenge is how to prescribe the right types of maintenance personnel monthly for accession and conversion to the JSF community as it get established over the next 11-year time horizon.

This thesis introduces the Marine Corps Maintenance Conversion Analysis Model (MCMCAM), a decision support tool that uses an Integer Linear Program (ILP) to prescribe the number of maintenance personnel for transition and accession into the JSF community. Demand for maintenance personnel is calculated using squadron activation schedules, and the requirements for maintainers in each squadron as identified in the USMC's Table of Organization (T/O). The MCMCAM determines the possible shortage or overfill of manning for each squadron, taking into consideration the rank and Years of Service (YOS) for each month of an 11-year planning horizon. The model considers four Military Occupational Specialties (MOS), and enumerates all possible career cycles (possible tours of duty over 11 years) that are available to the maintenance crew. By prescribing a path for each maintainer, MGMCAM captures the long-term implication of each transition and accession.

Using realistic data, we demonstrate use of the ILP under different levels of accession and allowed transition for four maintenance MOS.

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I. INTRODUCTION

The United States Marine Corps is facing the challenge of transitioning from legacy fixed-wing aircraft to a new aircraft system, the F-35B[1]. The F-35B (Figure 1), the Joint Strike Fighter, is an expensive asset, around US$150M each (Wikipedia, 2011a) with advanced short take-off and vertical landing (STOVL) capability, see Figure 1. Once it is delivered, USMC wants it to be immediately operational. This requires a detailed plan to man and train personnel during the JSF integration while maintaining adequate personnel in the legacy aircrafts communities until they are phased out. This thesis introduces the Marine Corps Maintenance Conversion Analysis Model (MCMCAM), a decision support tool developed to assist the USMC in their JSF integration. The tool uses Integer Linear Program (ILP) to prescribe the number of maintenance personnel for transition and accession into the new JSF community. The MCMCAM reveals the possible shortage or overfill of manning for each new squadron taking into consideration the rank and Years of Service (YOS) for each month of an 11-year planning horizon. The ILP helps the USMC answer the following questions: Is the current transition policy sufficient? How many maintenance personnel should be transitioned from legacy aircraft to the new aircraft as it stands up squadrons? What is the optimum rank and skill level distribution to be transitioned to those squadrons?

[1] The letter B designates the Marine Corps' variant of the Joint Strike Fighter.

Figure 1. During a flight demonstration, a Lockheed Martin F-35B was tested for hover capability at the Naval Air Station Patuxent River, MD (From Housch, 2010).

A. THESIS ORGANIZATION

The remainder of this chapter discusses the background of the JSF program, the Marine Corps F-35B version, the operation and maintenance of the F-35B versus the legacy aircraft, and the objective of this thesis. Chapter II presents the concept of aircraft maintenance, the introduction of the three levels of maintenance, and maintenance assignment and training. Chapter III introduces the MCMCAM and its ILP formulation. Chapter IV examines the model implementation and provides sample results. Finally, Chapter V gives further recommendations.

B. BACKGROUND

On November 16, 1996, two major aerospace companies, Lockheed Martin and Boeing, were selected to compete in concept demonstration of the JSF aircraft (Wikipedia, 2011b). The JSF project was originally formed by the merger of both the Common Affordable Lightweight Fighter (CALF) and Joint Advanced Strike Technology (JAST) projects. In 2001, Lockheed Martin was selected and awarded the contract of developing the next generation, or what is known today as the fifth generation, fighter aircraft, while Northrop Grumman and BAE Systems are principal partners in this project (Naval Air Systems Command, 2011a). The F-35 aircraft, which is the product of the JSF program, has matured on the idea of a relatively affordable fifth generation strike fighter that can be procured, operated, and supported with less cost than the legacy aircraft. The F-35 aircraft currently comes in three versions to support the U.S. Air Force, Marine Corps, and Navy. Because of its common design advantage, it is expected to give each service the opportunity to avoid higher costs of developing, procuring, operating, and supporting three separate tactical aircrafts (Gertler, 2009). The JSF is believed to be the last manned aircraft. A proper integration and transition to the new JSF system is the main objective of the Department of Defense (DoD). It is extremely important to bring this system to an operational level in a well-planned manner to avoid high implementation costs, which include costs for manning and transitioning from the old aircraft communities. The USMC faces the challenge of integrating their F-35B aircrafts while converting from F/A-18A+/C/D Hornet (Figure 2), AV-8B Harrier (Figure 3), and EA-6B Prowler (Figure 4) aircraft. Introducing the F-35B aircraft to the USMC will have a great impact on how it runs its aircraft support business compared to its aging aircraft communities, especially in the operation and maintenance fields.

Figure 2. USMC F/A-18C Hornet, a multi-role carrier capable fighter attacker aircraft (From McGarity, 2003).

In operation, the F-35B will replace three aging aircraft: F/A-18 A+/C/D Hornet, AV-8B Harrier, and EA-6B Prowler. The F-35B will carry more ordnance with greater range than the Hornet. It will offer the capability to operate from a variety of Navy ships as well as from austere landing sites similar to the AV-8B Harrier, and will ultimately possess electronic warfare technology similar to the EA-6B Prowler (Thomas, 2010). BGEN Bruce B. Byrum mentioned in his 1998 article in *The Hook* journal, that the Marine Corps is becoming more expeditionary and sustainable with the introduction of the JSF. He also mentioned that the USMC will search for ways to provide enhanced expeditionary command and control, and sustain fire ashore. He argues that the main objective is to reduce the size of the force and equipment that has to be supported ashore without sacrificing combat capability, and to reduce the number of different types of aircraft that the USMC supports (Byrum, 1998). However, equipment is not the only essential factor for operation readiness, manpower and its associated training is as important. As VADM Gerald L. Hoewing stated, “It’s people, after all, who bring our combat capability to bear; it’s people who give us the advantage” (Hoewing, 2004).

Figure 3. AV-8B Harrier II is a fighter-bomber aircraft used for ground attack and combat air patrol (From Adler, 2010).

The JSF has a revolutionary maintenance support system called Automatic Logistics Information System (ALIS). ALIS provides a complete logistic support solution for the JSF (Flight International, 2007), with improved features compared to the legacy aircraft logistic solution. The first feature is an intelligent aircraft designed to be highly reliable and easy to maintain, which includes a comprehensive prognostics and health management capability to increase flight safety, provide an improved logistics chain efficiency, and permit scheduling of logistic events to complement operational planning. The second is an improved automated tool and publication system that enables maintenance workers to more efficiently and effectively maintain the JSF, requiring less specialized training and more on-the-job training. This is accomplished by the use of Interactive Electronic Tech Manuals (IETMs). It allows a reduction in the workforce, and cross training over many sub-systems. The third feature is introducing the Joint Distributed Information System (JDIS) that implements advanced information technology connecting the JSF with the logistics infrastructure to provide proactive support. The final feature is the logistics infrastructure designed to be responsive to support requirements within a short timeframe and allow effective sorties generated at the lowest cost possible. It was introduced to create a vehicle inherently safer to operate, much more maintenance friendly, costing less to support, and fewer problems than Legacy aircraft. (Hess, Fila, & Henley, 2001).

Figure 4. EA-6B Prowler is a long-range, all-weather aircraft with advanced electronic countermeasures capability, supports Navy and Marine Corps (From Naval Air Systems Command, 2011b).

C. THESIS OBJECTIVE

This thesis introduces the MCMCAM, a decision support tool that uses an ILP to prescribe the number of maintenance personnel for transition and accession into the JSF community. Demand for maintenance personnel is calculated using squadron activation schedules and the requirements for maintainers in each squadron as identified in the USMC's Table of Organization. The MCMCAM determines the possible shortage or overfill of manning for each squadron taking into consideration the rank and Years of Service for each month of an 11-year planning horizon. The model considers four separate Military Occupational Specialties, and enumerates all possible career cycles (possible tours of duty over 11 years) that are available to the maintenance crew. By prescribing a path for each maintainer, MGMCAM captures the long-term implication of each transition and accession.

II. MARINE CORPS AVIATION MAINTENANCE

In military aviation, mission readiness is one of the key indicators of successful maintenance, and proper manning and training helps a maintenance organization meet this goal. By integrating the F-35B aircraft, the USMC expects to reduce the size of its aviation maintenance organization. This chapter presents the USMC maintenance level concept, which shows where maintainers from legacy communities could come from. It discusses maintenance assignment and training, where maintainers get assigned their specialty code MOS. This chapter also explains how and where maintenance training is conducted, and the training pipeline of new accessions. Finally, the chapter explores the literature on maintenance manning studies.

A. MAINTENANCE CONCEPT

The Naval Aviation Maintenance Program (NAMP) outlines the standards for maintaining readiness and safety levels acceptable to the Chief of Naval Operations and coordinating with the Commandant of the Marine Corps. Moreover, the Commander Naval Air Force (COMNAVAIRFOR) is responsible for ensuring compliance with all NAMP requirements. These requirements insure effective use of manpower, materiel, facilities, and funds in the naval aviation maintenance community (Commander Naval Air Forces, 2009). The Commander Naval Air Forces publishes the NAMP as COMNAVAIRFORINST 4790.2A (2009) and explains how the maintenance concept should be implemented in the naval aviation community. The concept in principle is quite straightforward; it has three levels of aviation maintenance (O-Level, I-Level, and D-Level) that differ in the complexity of work to be performed on an aircraft, the maintenance personnel's technical skill level, and facility capability. Furthermore, the concept of those three levels is the core maintenance concept of military aviation maintenance regardless of aircraft type, Air Force and Naval Aviation alike. However, the JSF design, when compared to the legacy aircraft, will reduce the total amount of required maintenance. It is expected to have one level fewer: the I-level maintenance requirement will be removed (Navy Training System Plan, 2001).

1. O-Level Maintenance

Organizational-Level (O-Level) maintenance is the responsibility of the operating unit. Maintenance performed at this level includes some scheduled inspections, replacement of minor parts, and some on-equipment preventive maintenance. This is a quick turnaround maintenance that supports mission capability for the user (Watt, 1999), (See Figure 5 for O-Level maintenance structure).

2. I-Level Maintenance

Watt (1999) mentioned that Intermediate-Level (I-Level) maintenance is performed at the Aviation Intermediate Maintenance Department either ashore at the Naval Air Station (NAS), on aviation capable ships, or at Marine Aviation Logistic Squadrons (MALS). I-Level maintenance typically requires higher skill levels and more manning hours than O-Level maintenance, and manpower is usually increased as well. It focuses more on system and subsystem repairs, like engines and other components of the aircraft. Figure 6 shows the standard structure of the I-level maintenance.

3. D-Level Maintenance

D-Level maintenance (Depot Level Maintenance) is performed on entire aircraft or certain repairable components. D-Level maintenance is the highest level of maintenance that can be performed on an aircraft. It requires more capable facilities and more skilled personnel. At this level, maintainers are capable of performing a whole-aircraft or component overhaul. Aircraft can go through major upgrades to their avionics or structure as well. Engines are usually handled by separate D-Level maintenance facilities. The objective of this level is performing maintenance that is beyond the capability of O-Level and I-Level. This activity is found at Naval Aviation Depots, contractors, and some aircraft manufacturers (Watt, 1999).

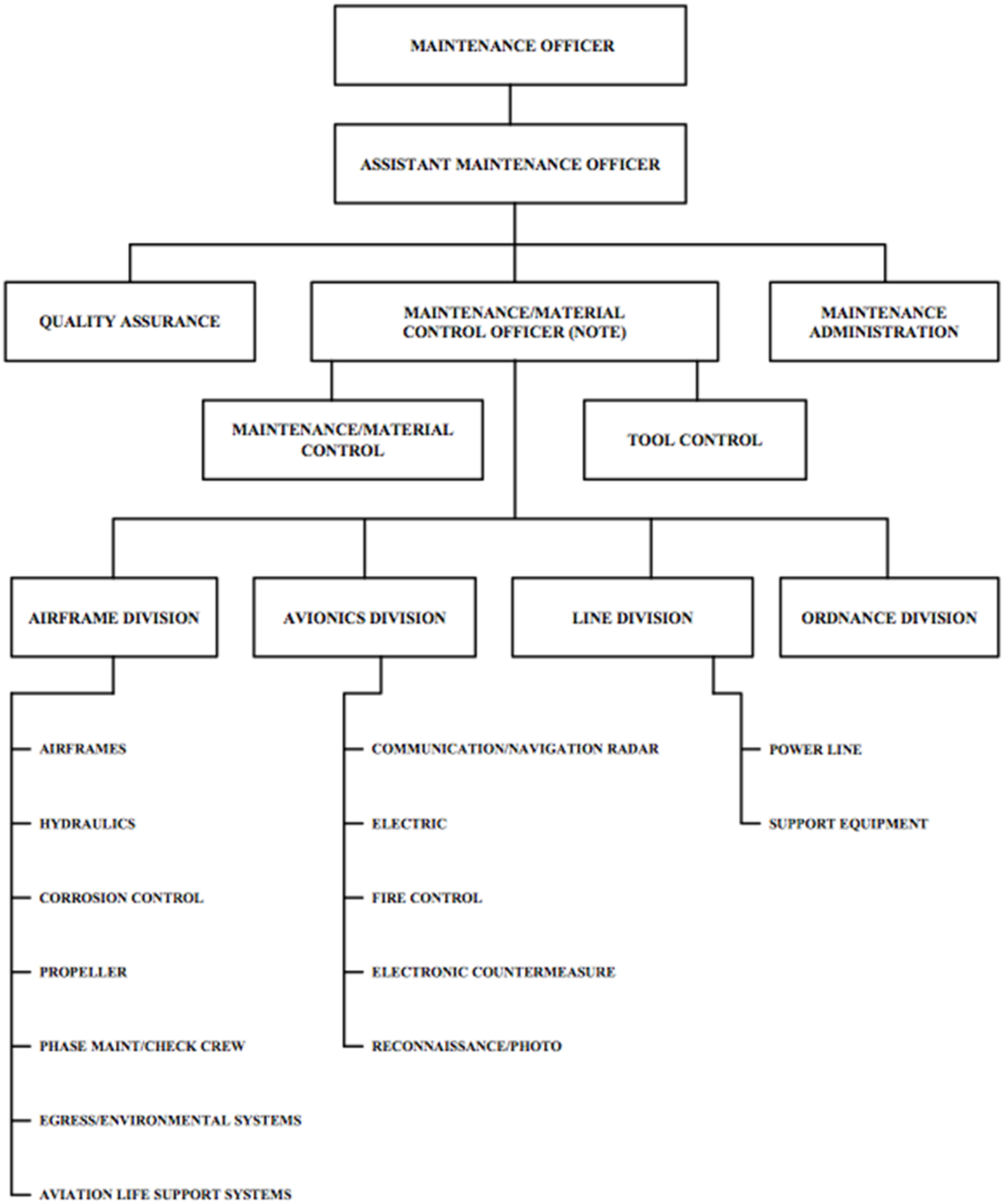

Figure 5. O-Level maintenance department line and staff relationships (From Commander Naval Airforce, 2009).

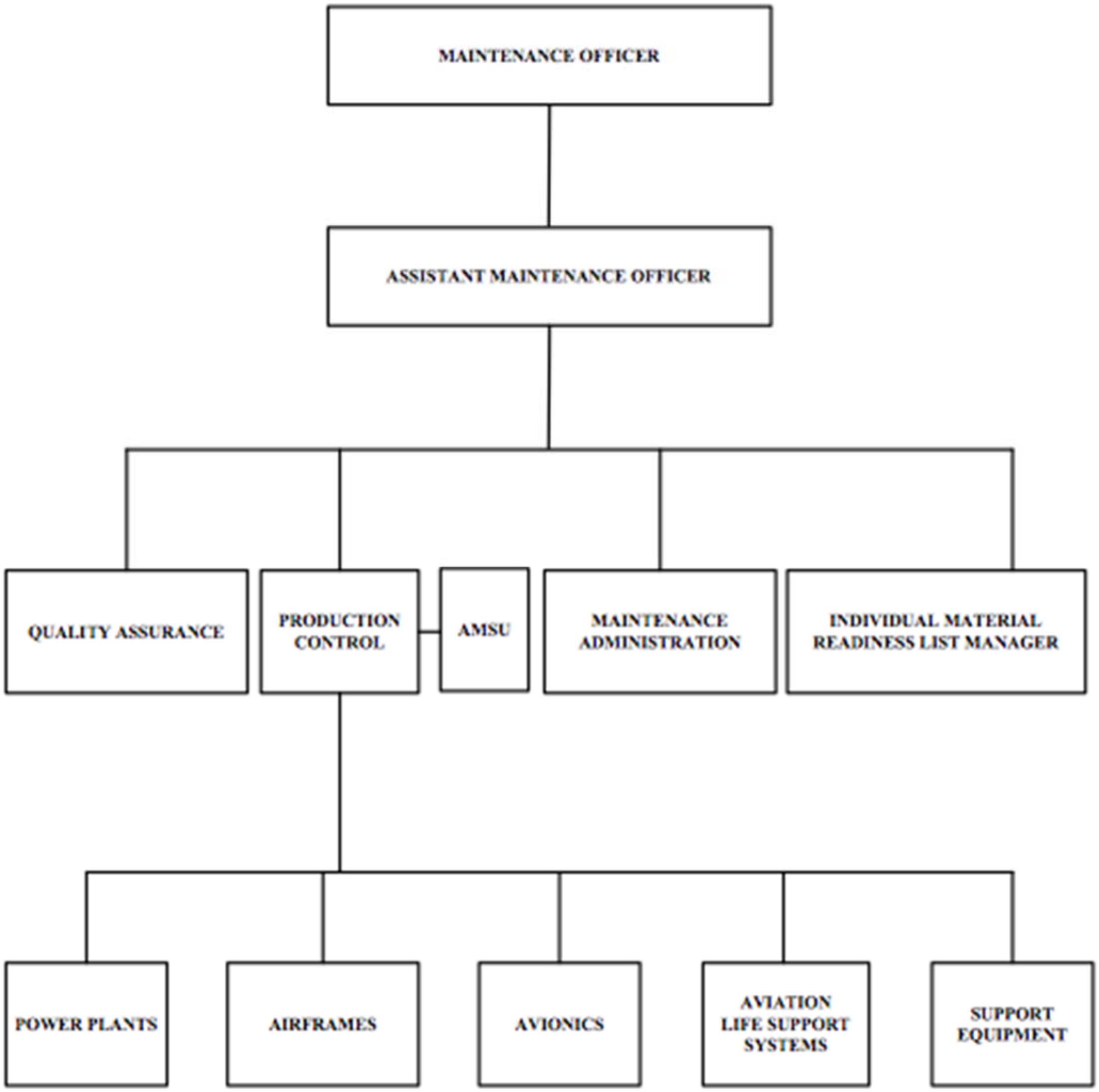

Figure 6. I-Level maintenance department organization (From Commander Naval Airforce, 2009).

B. MAINTAINERS' ASSIGNMENT AND TRAINING

The Deputy Commandant for Aviation sponsors the Naval Aviation Maintenance Training Program Administration, Marine Units, and ensures instructor manning is based on Naval Air Maintenance Training Group instructor calculations, anticipated requirements, and other workload factors. Marine Units conduct training leading to MOS qualification, provide a refresher to those maintainers returning from B-Billets (out of squadrons billets), and provide transition/conversion training (Department of the Navy, 2001). It is the Fleet Replacement Squadron (FRS) where actual training of pilots and mechanics on aircraft takes place. FRS provides aircraft replacement for fleet squadron attrition, and maintenance standardization to meet aircraft operations. The FRSs were formerly known as Replacement Air Groups, and commonly called "Rags" (Wikipedia, 2011c).

After boot camp, some enlisted marines get assigned to "A" school for their basic technical level qualification. Qualified marines who just graduated from "A" school are assigned an MOS that corresponds to their specialty. After that, they are assigned to a certain aircraft platform FRS for further qualification. Maintainers, after their FRS training, are expected to go to their designated operational squadrons and continue their advanced training while on the job. This squadron duty is identified in this thesis as an "A-billet." A maintainer could be assigned to "B-billet," which is out of squadron duty, during his advance years of service. It is expected that a new recruit does not start with a B-billet as a first assignment. USMC uses the MOS system to keep track of the occupational skills of military personnel and to match them to the proper billets available (Navy Training System Plan, 2001). Table 1 shows the required JSF maintainers by MOS. In this thesis, it is assumed that the training period is based on what rank and YOS the maintainer has at the time of transition.

RANKS	DESCRIPTION	MOS
E3-E7	Aircraft Mechanic	6218
E3-E7	Airframe Mechanic	6258
E3-E7	Aircraft Safety Equipment Mechanic	6288
E3-E7	Aircraft Communications/Navigation/Radar Systems Technician	6318
E3-E7	Aircraft Electrical Systems Technician	6338
E8-E9	Aircraft Maintenance Chief	From 61XX+62XX
E8-E9	Avionics Maintenance Chief	63XX

Table 1. USMC Required Military Occupational Specialty for each JSF squadrons. The concept of initial JSF manning requirements is to closely match legacy aircraft manning requirements.

C. LITERATURE REVIEW OF MAINTENANCE MANNING

MacKenzie, Miller and Hill (2010) explore the effect of maintenance manning utilizing Agent Based Modeling (ABM). Their article discussed the development of an agent-based model built to examine the effects of differing levels of maintenance manning on sortie generation capability, while exploring those effects on the resulting Combat Mission Readiness of a typical F-16 squadron.

The authors wrote:

> A model of the sortie generation process benefits from use of an ABM structure due to its identified complexity. Looking specifically at the inter-relationships between maintenance personnel across a variety of skill levels and job specialties and their potential outputs in terms of sortie production, an ABM provides a detailed individual-based perspective on the overarching process. The specific focus of this research involves the on-equipment maintenance portion of the sortie generation process. The

> simulation model is used to examine the effects of various levels of maintenance manning on sortie production and manning utilization while taking into account the specific abilities of individual maintenance personnel across a variety of job specialties and skill levels.

The analysis of MacKenzie, Miller, and Hill shows that slight changes in the configuration of available manning can have significant effects on a unit's maintenance capacity and the ability to develop over time. This has direct consequences to any maintenance unit's capability to sustain and support a wing's Combat Mission Readiness requirement (MacKenzie, Miller, & Hill, 2010).

According to Oliver (2001) research which adresses the Air Force's mission capability rate forcasting, that the aggregate aircraft total Not Mission Capable (NMC) rate due to maintenance for all aircrafts was steadily increased from 14 percent to 18.2 percent while total not mission capable rate due to supply also increased from 5.5 percent in fiscal year (FY) 86 to 17.5 percent in FY00. The mission capable rate is a rate primarily used to identify the percentage of aircraft that are able to perform their primary missions, as Oliver defines it. Oliver explains that the current Air Force's forcasting model that predict the mission cabability rate does an exceptional job of predicting mission capable rates based on funding data and other associated planning factors. However, he argue that it does not explain the key drivers that influence mission capable rates, which limits its effectiveness as a management and decision-making tool. He further explanes that other variables, such as maintenance manning and experience levels, retention, fix rates, operations tempo, spare parts issues, and aircraft systems reliability and maintainability are as well related to mission capable rates. Part of his research is using these variables and others to develop regression models that provide more insightful forecasts. One of his argument was that personnel are the most dificult area to assess, and during the course of his analysis he mentioned the folowing:

> The results of the analysis were very similar to the findings of other studies that analyzed how personnel levels relate to mission capable rates. The underlying factor in the personnel data appeared to be experience. Whether the data was analyzed by grade, skill level or percent of authorizations filled, the story was the same as the number of inexperienced personnel (defined as 3-levels and E-3s) increased, mission

> capable rates decreased. Conversely, as experience increased (5, 7 and 9 levels as well as E-4 – E-9) mission capable rates increased. To better understand these relationships in an operational environment, the ratio of 3- levels to other skill levels was thought to be a useful measure of personnel conditions (experience mix) that might exist in a typical maintenance complex. The ratios were created to model the level of responsibility more senior and experienced personnel are shouldered with when training and supervising new/inexperienced personnel. When analyzed, increases in the ratio of 3-levels to either 5 or 7-levels (or both) are negatively correlated to mission capable rates. An drill-down analysis of these ratios for specific AFSCs was less clear. Some AFSCs, such as crewchiefs and flightline avionics, exhibited the same trends as the top-level analysis of the ratios; however, skill level ratios for other AFSCs, such as engines and structures, demonstrated positive correlation with mission capable rates. This could indicate that mission capable rates are more sensitive to skill level imbalances in certain career fields more than others.

Oliver has analyzed the model he built theoretically and empirically to measure the models predictivity reliability. By using multiregression analysis, he was able to find those variable that demonstrate significant relationship with mission capable rate. His main objective was to find the deficiency in forcasting the mision capability rate used by the Air Force at that time, and how different variables in the Air Force have impacted F-16C/D aircraft readiness as related to mission capable rates (Oliver, 2001).

III. PROBLEM DEFINITION AND FORMULATION

The USMC has already established the manning requirements to populate the new JSF squadrons. However, the process of properly prescribing the right type and number of maintenance personnel for conversion and accession over 11 years remains a challenge. Following Holloway's (2010) modeling for pilots, this thesis generates career paths by enumerating all possible career cycles (tours of duty) that are available to a maintainer. An ILP prescribes the optimal number of maintainers for transition and accession into the new JSF squadrons, for each month, over an 11-year planning horizon by selecting the maintainer career paths that best satisfy the billet requirements by rank, experience, and YOS. The maintainer's addition into the new community is dependent upon the availability of aircraft and training hours. The objective is to minimize the summation of elastic penalties that are associated with manning shortages and overages, while filling all billet demands over the prescribed period.

A. JSF TRAINING PLAN

The 33rd Fighter Wing (FW) is the Joint Integrated Training Center located at Eglin Air Force Base, Florida. This Fighter wing is known as the "Nomads" for its constant travel throughout the world, and was designated as the flying and maintenance training wing for the JSF organized under Air Education and Training Command's 19th Air Force by the DoD in October 2009. The 33rd FW operates seven squadrons aligned under the Operations and Maintenance Groups. Initially, the 33rd Operation Group consists of four squadrons, of which one of them is the VMFAT-501, training Marine pilots with the F-35B STOVL variant. The 33rd Maintenance Group (MXG) consists of three squadrons: the 33rd Aircraft Maintenance Squadron, providing flightline maintenance support; the 33rd Maintenance Squadron, providing intermediate-level back-shop support; and the 33rd Maintenance Operations Squadron, providing maintenance control and other logistics support functions. The MXG will be responsible for the integration and execution of Marine Corps as well as Navy and Air Force maintenance policies and procedures (Team Eglin Public Affairs Office, 2010).

B. DEMAND FOR MAINTAINERS

The demand for maintainers, based on the USMC plan, is driven by the initial requirements for the establishment of new JSF squadrons, which is based on the squadron T/O. The first squadron, as mentioned above, is the VMFAT-501 with inventory of 20 F-35B planned. The maintenance personnel required for such a squadron are categorized into three categories based on the delivery of aircraft to this squadron.

- Personnel required prior to standup of a squadron
- Personnel required after standup of a squadron for the Initial Operation Capability (IOC)
- Personnel required after the IOC

At the time of this thesis, there were personnel that had been converted to the JSF, to satisfy the standup requirement of the first VMFAT squadrons. Each type of squadron and the planned requirements of personnel are discussed in the following chapter. These tables show the required personnel starting in the year 2011 until 2022, presenting 11years of planning for three types of squadron: 10-,16-, and 20-aircraft.

C. SOURCE OF MAINTAINERS

Maintainers are considered either transitioned from deactivated squadrons like the F/A-18, AV-8B, and EA-6B, or new recruits (accessions) who have just finished their initial training and have been assigned an MOS. It should be noted that as far as training, it requires a transitioned Marine fewer training hours than the accessions to bring them in compliance to JSF requirements. The next chapter shows the squadron shutdown timetable for each operational or training squadron and the available personnel.

D. TRANSITION TRAINING REQUIREMENTS

The training requirement is based on whether the maintainer is transitioned or accessioned. For the transitioned, the requirement depends on which MOS code he carries from the old community as to how much experience is transferred to the new system. For the purpose of this thesis, all different types of MOS transitioned from the old communities are handled as one type, which is identified in the model as experienced “Transitioned” and only YOS and rank are relevant.

E. CAREER CYCLE ENUMERATION

As in Holloway (2010), a career path is the history of service assignments a Marine accumulates as he or she rotates between units and duty stations. The maintainer's model in this thesis recognizes each billet assignment as a career cycle with a specific duration. The whole career of an individual maintainer consists of a chain of career cycles identified as a career path as in Holloway. Table 2 illustrates the possible career cycle choices based on assignment duration. The career cycle information was gathered from the Marine Corps Personnel Assignment Policy document (Department Of The Navy, 1994).

	FRS	**1st Tour**	**2nd Tour**	**3rd Tour**
Career Paths	9-12 Months	24 Months	36 Months	100 Months
A-Billet		36 Months		
B-Billet		48 Months		
		60 Months		
		150 Months		
Examples		24 Months	36 Months	100 Months
		36 Months	36 Months	100 Months
		48 Months	36 Months	100 Months
		60 Months	36 Months	100 Months
		150 Months	36 Months	100 Months

Table 2. Possible career cycle choices based on assignment duration. The first example shows a career path for a maintainer that has finished an entry-level training at the FRS and was assigned to an operational squadron for 24 months. The second tour for him was an out-of-squadron tour, during which he was gone for 36 months and then back to squadron duty for 100 additional months.

The maintainer's model in this thesis represents the career path as column vector of binary digits. Those binary digits represent assignments, "1" for an in-squadron billet or A-billet and "0" for out-of-squadron duty or B-billet. The first example is the career path for a maintainer that has finished an entry-level training at the FRS and was assigned to an operational squadron for 24 months. The second tour for him was an out-of-squadron tour, during which he was gone for 36 months and then back to squadron duty for 100 additional months. Hence, the vector representation for this career path would be 24 "1s" followed by 36 "0s" and then by 100 "1s."

To reduce the possible number of career paths, the same assumptions utilized in Holloway (2010) are used here and, for consistency, the formulation below adopts, as much as possible, the same notation found in Holloway (2010).

F. FORMULATION

1. Sets

t, ta	time periods (months) [~142]
r	rank [7]
y	years of service (YOS) [~22]
p	types of already transitioned maintainer [~12]
c	career path (columns) [~1322]
$cp(c,p)$	career path c for already transitioned maintainers of type p
$ct(c,t)$	career path c starts in time period t
$cy(c,y)$	career path c begins with y years of service
$ctr(c,t,r)$	career path c has rank r in period t

2. Data

$req_{r,t}$	requirement for maintainers of rank r in squadrons in period t
$reqb_{r,t}$	requirement for maintainers of rank r out of squadrons in period t
$nt_{t,y}$	maintainers available to transition in period t with y YOS
nn_t	new maintainers available in period t
fh_t	available training hours in period t
$fhours_{c,t}$	training hours for path c required in period t
$pinit_p$	initial number of maintainers of type p already transitioned
$maxwait$	years a maintainer remains available for transition

3. Calculated Data

$s_{c,t,r}$ fraction of maintainers starting career path c having rank r at time t

$sb_{c,t,r}$ fraction of maintainers starting career path c having rank r and being out of a squadron at time t

4. Variables

X_c number of maintainers starting career path c [integer]

$SUB_{r,t}$ number of maintainers of rank r used to fill squadron billets for rank r+1 in period t

$SUBB_{r,t}$ number of maintainers of rank r used to fill B-billets for rank r+1 in period t

EFH_{ta} backlog of training hours in period ta

5. Formulation

Minimize *elastic penalties* (0)

Subject to:

$$\sum_{c:ctr(c,t,r)} s_{c,t,r} X_c + SUB_{r-1,t} - SUB_{r,t} \overset{\circ}{=} req_{r,t} \qquad \forall r \in R, t \in T \quad (1)$$

$$\sum_{c:ctr(c,t,r)} sb_{c,t,r} X_c + SUBB_{r-1,t} - SUBB_{r,t} \overset{\circ}{\geq} reqb_{r,t} \qquad \forall r \in R, t \in T \quad (2)$$

$$\sum_{\substack{t-maxwait<t'\leq t \\ c:ct(c,t')\wedge cy(c,y)}} X_c \leq \begin{cases} nt_{t,y} & y>1 \\ nn_t + nt_{t,y} & y=1 \end{cases} \qquad \forall t \in T, y \in Y \quad (3)$$

$$SUB_{r,t} \leq \sum_{c:ctr(c,t,r)} s_{c,t,r} X_c \qquad \forall r \in R, t \in T \quad (4)$$

$$SUBB_{r,t} \leq \sum_{c:ctr(c,t,r)} sb_{c,t,r} X_c \qquad \forall r \in R, t \in T \quad (5)$$

$$\sum_{c \in C} fhours_{c,ta} X_c + EFH_{ta-1} \leq fh_{ta} + EFH_{ta} \qquad \forall ta \in T \qquad (6)$$

$$\sum_{c:cp(c,p)} X_c = pinit_p \qquad \forall p \in P \qquad (7)$$

$$X_c \in Z^+ \qquad \forall c \in C \qquad (8)$$

As in Holloway's (2010) formulation, the objective here is to minimize the sum of weighted elastic variables associated with shortages and excesses of maintainers by rank *r*, in each month of the planning horizon.

Constraint sets (1) and set (2) compute the number of maintainers above or below the number required each month of the planning horizon for squadron and out of squadron requirements, respectively. Constraint set (3) limits the number of maintainers for transition and new accessions. Constraint sets (4) and set (5) limit the number of substitutions of lower-rank enlisted for higher-rank jobs to the number of enlisted available at the lower rank in any time period. Constraint set (6) accounts for training hours. Constraint set (7) ensures assignment of maintainers previously transitioned or accessed. Constraint set (8) declares integer variables.

IV. IMPLEMENTATION, RESULTS, AND ANALYSIS

A. IMPLEMENTATION

1. Graphical User Interface (GUI)

The MCMCAM is implemented in Microsoft Excel (2007). This graphical user interface is a modified version of the Marine Corps Pilot Conversion Analysis Tool (Holloway, 2010). The GUI is implemented in four different workbooks; each corresponds to one of the E3-E7 MOSs 6218, 6258, 6288, and 6388. Each workbook consists of 20 worksheets. The first five worksheets are static and should only be updated if a planner wishes to evaluate delays in delivery schedule or changing a maintainer's assignment policy. The following eight worksheets are the user input worksheets. The user can update data on these sheets to reach acceptable transition plans. The last seven "results" worksheets are created by a macro that reads results from the General Algebraic Modeling system (GAMS), output files. GAMS generates each instance that we solve using CPLEX version (11.2.0). These data are categorized below in the same sequence they appear in the GUI for each workbook of the four MOSs.

a. Planning Horizon

The USMC has provided the Planning Horizon data, under the "control" worksheet, for the activation of the JSF community. The data in this worksheet consists of many columns, which are shown in Table 3. Column one lists fiscal years of the planning period, based on the Marine Corps requirement. USMC plans to have 24 JSF squadrons operational by the year 2022. The model assumes 12 time periods for each year corresponding to the month of the year. The maximum number of columns for the ILP is 200,000 (more than enough for all instances considered). All maintainers are considered experienced. The summer column together with the "Can Start" column defines the assignment policy of when a maintainer can start as part of the F-35B community and when they can start a new tour. The ranks of the personnel considered here are from E3 to E9 and are fixed for all workbooks. The last five columns of this worksheet are related to the Years of Service (YOS) and the expected retention of each rank.

Planning Horizon in Years and Months						Years of Service, Rank, Retention, Experience				
Fiscal Years	Time Periods	Fiscal Year	Summer	Can Start	Ranks	YOS	Rank	Retention (1Yr)	Train Exp	Retention (Cum.)
FY11	tDEC10	FY11	FALSE	TRUE	E3	y01	E3	100%	exp	100%
FY12	tJAN11	FY11	FALSE	TRUE	E4	y02	E3	95%	exp	95%
FY13	tFEB11	FY11	FALSE	TRUE	E5	y03	E3	95%	exp	90%
FY14	tMAR11	FY11	FALSE	TRUE	E6	y04	E4	89%	exp	80%
FY15	tAPR11	FY11	FALSE	TRUE	E7	y05	E5	62%	exp	49%
FY16	tMAY11	FY11	FALSE	TRUE	E8	y06	E5	87%	exp	43%
FY17	tJUN11	FY11	TRUE	TRUE	E9	y07	E5	87%	exp	37%
FY18	tJUL11	FY11	FALSE	TRUE		y08	E6	87%	exp	33%
FY19	tAUG11	FY11	FALSE	TRUE		y09	E6	87%	exp	28%
FY20	tSEP11	FY11	FALSE	TRUE	Experience Levels	y10	E6	87%	exp	25%
FY21	tOCT11	FY12	FALSE	TRUE	exp	y11	E6	87%	exp	21%
FY22	tNOV11	FY12	FALSE	TRUE		y12	E6	87%	exp	19%
	tDEC11	FY12	FALSE	TRUE		y13	E6	87%	exp	16%
	tJAN12	FY12	FALSE	TRUE	Max Tours	y14	E7	87%	exp	14%
	tFEB12	FY12	FALSE	TRUE	200000	y15	E7	87%	exp	12%
	tMAR12	FY12	FALSE	TRUE		y16	E7	87%	exp	11%
	tAPR12	FY12	FALSE	TRUE		y17	E7	87%	exp	9%
	tMAY12	FY12	FALSE	TRUE		y18	E7	87%	exp	8%

Table 3. Snapshot of the control tab that outlines the sets that are used in the formulation. This tab is fixed for each MOS and across all seven spreadsheets.

b. Maintenance tours

In worksheet “Tours,” a table of possible tours, or billet assignments, was created based in part on the USMC document MCO P1300, “Marine Corps Personnel Assignment Policy” (Department of the Navy, 1994). The table shows the possible options of each tour for each career path. The table shows the possible filling of A-billet (in squadron tour) or B-billet (off squadron tour). And as explained in Chapter III, each billet assignment is considered as a career cycle with a specific duration. The whole career of an individual maintainer consists of a chain of career cycles identified as a career path. Table 4 illustrates the possible career cycle choices based on assignment duration.

Tours

Length

Tour1	Tour2	Tour3	Tour4
24	36	100	20
36			
48			
60			
150			

A-billet

Tour1	Tour2	Tour3	Tour4
TRUE	FALSE	TRUE	TRUE
TRUE			
TRUE			
TRUE			
TRUE			

Table 4. Lengths of every career cycle alternative for a tour. True and False are used as flags to identify whether the assignment is an in squadron billet or not.

c. Maintenance B-Billet Requirement

For the B-billet requirement in worksheet "reqb," a table of columns of ranks and rows of time periods are created. For each rank during a given time period a ratio was calculated based on historical data to determine the fraction of the total number of marines of each rank expected to serve in a B-billet. These data differ for each MOS.

	Rank						
Period	E3	E4	E5	E6	E7	E8	E9
tDEC10	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01
tJAN11	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01
tFEB11	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01
tMAR11	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01
tAPR11	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01
tMAY11	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01
tJUN11	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01
tJUL11	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01
tAUG11	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01
tSEP11	0	0.068966	0.222222	0.3	0.111111	0.038462	0.01

Table 5. Snapshot of the B-billet requirement “reqb” tab by month for each rank. This data represents MOS 6218. For example, for E9 the value is 0.01 indicates that only 1% of all E9 marines in MOS 6218 are required to serve out-squadron job or B-billet.

d. Initial Transition to F-35B

This sheet shows personnel that were transferred to the new JSF community prior to the initial time period of the model. This information is part of the initial conditions and is implemented in tab “init_trans.” Based on the data given, 12 maintainers have already been transferred and the remaining training requirement for them is five hours of training in six different periods. In the model, initial transitioned personnel are based on YOS.

YOS	Transitioned	Periods Before Start	Train Hours Required	Train Periods Required
y01	0	0	5	6
y02	0	0	5	6
y03	0	0	5	6
y04	0	0	5	6
y05	0	0	5	6
y06	0	0	5	6
y07	1	0	5	6
y08	1	0	5	6
y09	1	0	5	6
y10	2	0	5	6
y11	1	0	5	6
y12	1	0	5	6
y13	1	0	5	6
y14	2	0	5	6
y15	1	0	5	6
y16	1	0	5	6

Table 6. Initial set of JSF maintainers who have already transitioned to the JSF community. The "Transitioned" column defines the number of maintainers for each YOS that are in the community prior to the initial time period of the model. The remaining hours and months required for training are also listed.

e. Available Personnel for Transition

Tables of available personnel are based on YOS and the time period they are available for each MOS used in this model. Table 7 illustrates marines available for transition based on their YOS and the time period they are available. It is assumed that only marines with up to 16 YOS can be transitioned. Above 16 YOS is considered too close to retirement to transition. In Table 8, the core-cadre E5-E7, YOS range of y05 to y18, require a longer training period than the other ranks. The longer training period allows preparation to be authorized to sign off on training documents of others' training completion. These data are implemented in the "avail_pool" tab in the model spreadsheet.

YOS	Personnel	When Available
y01	5	tDEC10
y02	10	tDEC10
y03	15	tDEC10
y04	26	tDEC10
y05	29	tDEC10
y06	25	tDEC10
y07	27	tDEC10
y08	28	tDEC10
y09	23	tDEC10
y10	20	tDEC10
y11	10	tDEC10
y12	22	tDEC10
y13	18	tDEC10
y14	14	tDEC10
y15	18	tDEC10
y16	16	tDEC10

Table 7. Available maintainers by YOS.

Rank	YOS	Hours	Periods
E3	y01	5	3
E3	y02	5	3
E3	y03	5	3
E4	y04	5	3
E5	y05	10	5
E5	y06	10	5
E5	y07	10	5
E5	y08	10	5
E6	y09	10	5
E6	y10	10	5
E6	y11	10	5
E6	y12	10	5
E6	y13	10	5
E6	y14	10	5
E7	y15	10	5
E7	y16	10	5
E7	y17	10	5
E7	y18	10	5
E8	y19	5	3
E8	y20	5	3
E8	y21	5	3
E9	y22	5	3

Table 8. Training requirements table. Shaded data in this table represent the core-cadre training requirements, which are from E5 to E7.

2. Planner Input

a. Legacy Squadrons Deactivation Schedule

Legacy aircraft communities have a predetermined schedule of stand-down; these data are in worksheet “nt_Harrier, nt_Hornet.” Tables of expected available personnel and type of YOS at the scheduled step-down period are provided by the USMC. There are 7 Harriers squadrons who will step down from 2014 to 2021 and one training squadron in January 2019. In the Hornet community, 12 squadrons will step down from 2013 to 2022 and three training squadrons from 2018 to 2021. In the Prowler community there are two operation squadrons and one training squadron that will step down during the period from 2021 to 2022 (see Table 9).

AV-8B Harrier standown schedule							
	Operational Squadrons				FRS (Training) Squadrons		
YOS	Pers/Sq	Avail			YOS	Pers/Sq	Avail
y01	3	1			y01	5	1
y02	5	2			y02	8	3
y03	17	8			y03	34	18
y04	11	6			y04	18	9
y05	3	2			y05	2	2
y06	3	2			y06	2	1
y07	2	1			y07	1	1
y08	2	1			y08	1	1
y09	1	1			y09	1	0
y10	1	1			y10	1	1
y11	1	0			y11	0	0
y12	1	0			y12	0	0
y13	1	1			y13	0	0
y14	1	1			y14	1	1
y15	1	0			y15	1	0
y16	1	1			y16	1	1
	Standdowns					Standdowns	
	Period	Squadrons				Period	Squadrons
	tJAN14	1				tJAN19	1
	tJAN17	1					
	tJAN18	1					
	tJAN19	1					
	tJAN20	2					
	tJAN21	1					

Table 9. AV-8B Harrier deactivation schedule and the available personnel that correspond to MOS 6218.

b. New Accession

New accessions are limited to the number of personnel coming out of the basic school/recruit training and the number is affected by their initial active duty obligation (Department of the Navy, 1994). It was hard to predict the number of new recruits; therefore, for simplicity, an assumed number was used for each time period, and at the end of the analysis section it is clear how much impact the assumed numbers have on the personnel assignment outcome. The assumption at first was two per month in all instances from December 2011 onward (see Table 10).

tDEC10	0
tJAN11	0
tFEB11	0
tMAR11	0
tAPR11	0
tMAY11	0
tJUN11	0
tJUL11	0
tAUG11	0
tSEP11	0
tOCT11	0
tNOV11	0
tDEC11	2
tJAN12	2
tFEB12	2
tMAR12	2
tAPR12	2
tMAY12	2
tJUN12	2
tJUL12	2
tAUG12	2
tSEP12	2
tOCT12	2
tNOV12	2
tDEC12	2

Table 10. New personnel available for accession after finishing basic training. Data in the spreadsheet lists availability up to September 2022.

c. Squadron Stand-up Schedule

The requirements for each 10-plane, 16-plane, 20-plane JSF stand-up squadron were incorporated in each spreadsheet for each of the four MOSs. In Table 11, an example of 10-plane squadron requirement is shown. The first two columns provide the month of the planning horizon that squadrons will activate. The squadron activation requirements consist of three main phases, and for each phase there are different manning requirements. The initial phase, which starts six months before the squadron stands up, is called RFO (Ready For Operation). The second phase begins after a squadron stands up and continues for eight months, and it is called IOC (Initial Operation Capability). The final phase starts after IOC and continue for six months is called the Full Complement phase. Requirements for these three phases can change by FY over the planning horizon.

10-Plane squadron standup schedule						Year											
Period	Squadrons		Personnel requirements	Experience	Rank	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22
tAPR12	1		RFO (Ready for Operation)	exp	E3	0	0	0	0	0	0	0	0	0	0	0	0
tSEP13	1		6	exp	E4	0	0	0	0	0	0	0	0	0	0	0	0
tJAN15	1		periods prior to standup the	exp	E5	3	0	3	6	6	0	3	3	9	9	9	6
tMAY15	1		following personnel must be availabl	exp	E6	2	0	2	4	4	0	2	2	6	6	6	4
tNOV15	1			exp	E7	2	0	2	4	4	0	2	2	6	6	6	4
tAPR16	1			exp	E8	0	0	0	0	0	0	0	0	0	0	0	0
tMAY18	1			exp	E9	0	0	0	0	0	0	0	0	0	0	0	0
tDEC18	1																
tMAY19	1		IOC (Initial Operation Capability)	exp	E3	7	7	0	7	7	14	7	7	14	21	28	21
tSEP19	1		8	exp	E4	9	9	0	9	9	18	9	9	18	27	36	27
tJAN20	1		periods after standup the following	exp	E5	4	4	0	4	4	8	4	4	8	12	16	12
tAPR20	1		additional personnel must be availab	exp	E6	2	2	0	2	2	4	2	2	4	6	8	6
tAUG20	1			exp	E7	1	1	0	1	1	2	1	1	2	3	4	3
tNOV20	1			exp	E8	2	2	0	2	2	4	2	2	4	6	8	6
tFEB21	1			exp	E9	1	1	0	1	1	2	1	1	2	3	4	3
tJUL21	1																
tOCT21	1		Full complement	exp	E3	0	0	0	0	0	0	0	0	0	0	0	0
tJAN22	1		6	exp	E4	0	0	0	0	0	0	0	0	0	0	0	0
tJUN22	1		periods after IOC the following	exp	E5	0	0	0	0	0	0	0	0	0	0	0	0
tSEP22	1		additional personnel must be availab	exp	E6	0	0	0	0	0	0	0	0	0	0	0	0
				exp	E7	0	0	0	0	0	0	0	0	0	0	0	0
				exp	E8	0	0	0	0	0	0	0	0	0	0	0	0
				exp	E9	0	0	0	0	0	0	0	0	0	0	0	0

Table 11. Requirements of 10-plane squadron. The maintenance personnel required for such a squadron are categorized into three categories based on the delivery of aircraft to this squadron and the fiscal year: first, personnel required prior of the standup of a squadron, six months prior; then, personnel required after standup of a squadron for the Initial Operation Capability, eight months after standup; finally, personnel required after the IOC, six months after IOC.

d. Aircraft Delivery Schedule

Table 12 is the last user input worksheet, "fh." These data are derived from the aircraft delivery schedule; it lists all planes delivered and the number of hours available for training during each period of the planning horizon (used in the formulation to calculate *fht*). A percentage of the available training hours will be subtracted from each aircraft to compansate for losses in the event of unscheduled maintenance, weather, etc.

Period	F-35 aircraft	training hours/aircraft	overhead
tDEC10	1	25	27.75%
tJAN11	2	25	27.75%
tFEB11	1	25	27.75%
tMAR11	2	25	27.75%
tAPR11	2	25	27.75%
tJUN11	1	25	27.75%
tOCT11	1	25	27.75%
tDEC11	1	25	27.75%
tJAN12	2	30	27.75%
tMAR12	1	30	27.75%
tMAY12	1	30	27.75%
tJAN13	3	35	27.75%
tFEB13	1	35	27.75%
tMAR13	1	35	27.75%
tAPR13	1	35	27.75%

Table 12. Aircraft delivery schedule. In the worksheet, the data runs up to Aug 18. For example, an aircraft will be delivered on October 2011 and only 77.25% of the 25 training hours are available.

3. Results

Output is generated in Comma Separated Value (CSV) files that get imported by a macro activated in the spreadsheet. One of the main results shows the model optimal fill, available maintainers to fill requirements, to the required billets by the activation of the new JSF squadrons over the transition horizon. Figures 7 and 8 describe billet requirements over the prescribed time period against the model filling those billets for rank E6 of MOS 6218 and 6258, respectively. The model generates similar graphs for E3 through E9 for each MOS.

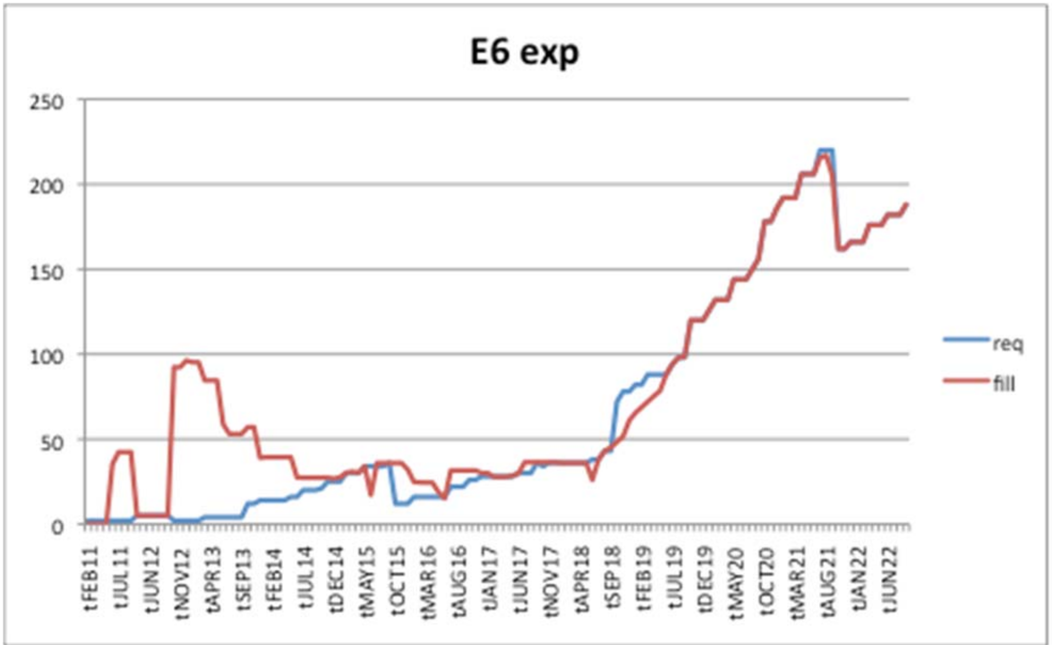

Figure 7. Requirement vs. fill for E6 of MOS 6218 over the transition horizon from FY2011 through FY2022. The graph above shows that these billets are almost met but not for every month, and sometimes are over filled.

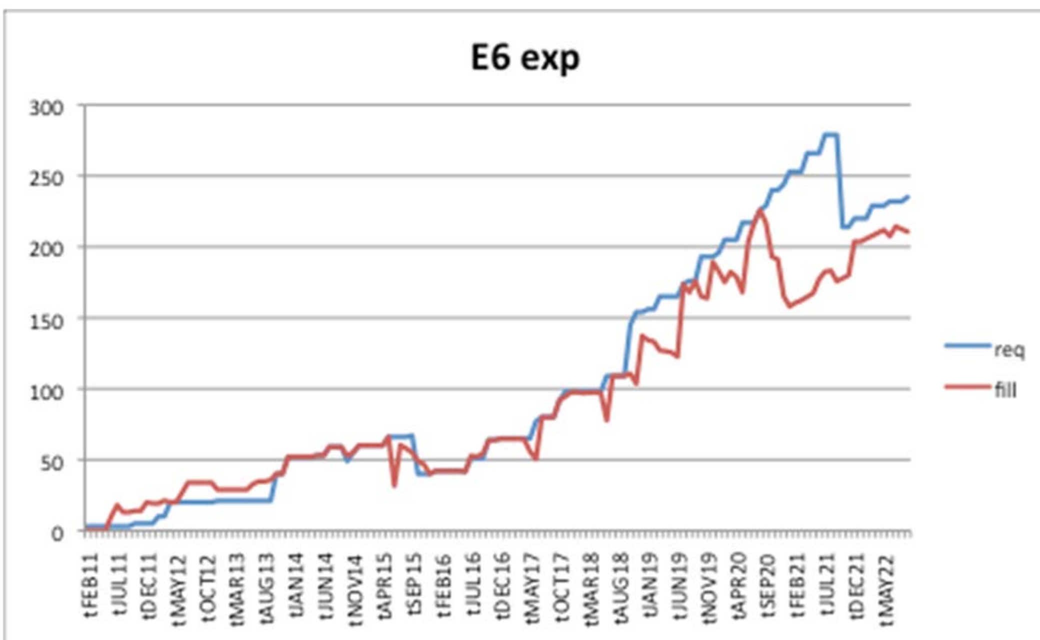

Figure 8. Requirement vs. fill for E6 of MOS 6258 over the transition horizon from FY2011 through FY2022. Unlike Figure 7, it is clear that there is a minor shortage that starts from OCT16 and continues to the end of the planning horizon, which could be covered by the lower ranks.

The model incorporates one-up substitution and a low penalty for substitution. It allows the priority to fill the higher ranks first if possible, which explains the shortage in the lower ranks in most of the examined MOSs. Figure 9 shows an aggregate prescription for MOS 6218 by YOS over 11 years. MCMCAM generates different results for each MOS used in this model due to their specific requirements.

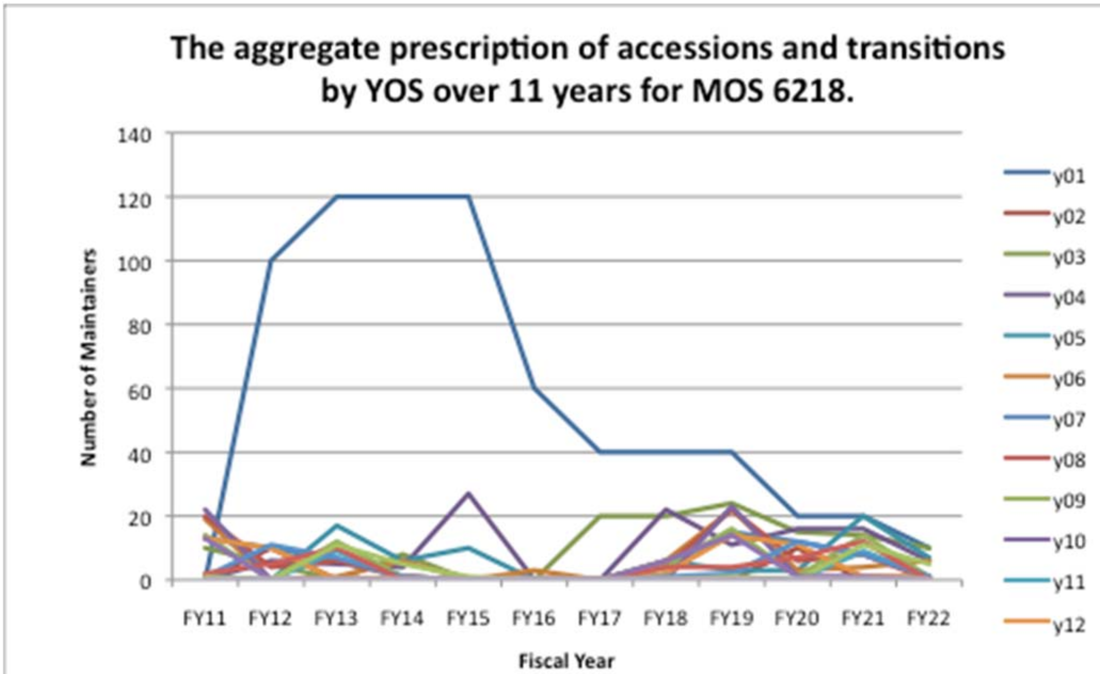

Figure 9. Prescribed accessions and transitions from FY2011 to FY2022 for MOS6218. (This figure is best viewed in color.)

B. ANALYSIS

By inspecting the results generated by the MCMCAM for each of the four MOSs, it is clear that the transition plan will face some challenges. The primary challenge is the significant shortage in maintainers at lower ranks especially E3 through E6 to fill the required billets over the planning horizon. We investigate changing levels of new accessions to reduce these shortages.

1. Increase New Accession

Taking MOS6218 as an example and at access quantity of 2 per month, all the ranks E3 through E9 are short and not meeting the requirement especially at the second half of the planning horizon (see Figures 10 and 11). At rank E3 for example, we see a short period of satisfying the requirement up to January 2015 then a drop as E3s are used to satisfy requirements for short E4s (see Figure 10). By increasing the number of allowed accessions each month to 20, the requirement for E3s (see Figure 12) and other ranks are almost fully satisfied. The large number of accessions above the requirement for E3s can be attributed to the need to have maintainers of higher ranks available in the later years of the time horizon (see, for example, Figure 13).

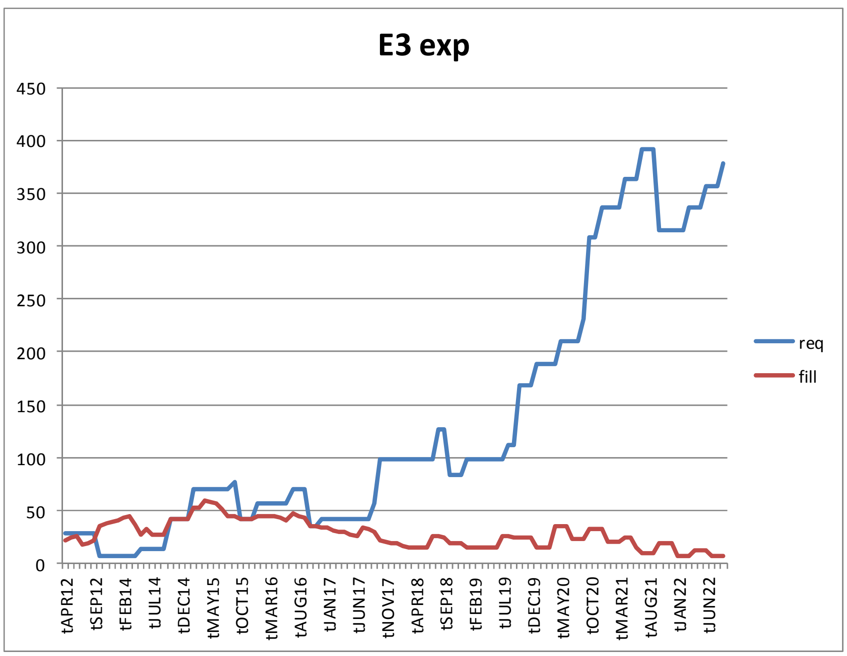

Figure 10. Rank E3 for MOS 6218 shows a short effort to fill the requirement up to January 2015 then a drop in that effort takes place afterwards, diverging from the increased demand, and therefore shows a significant shortfall over the rest of the planning time horizon.

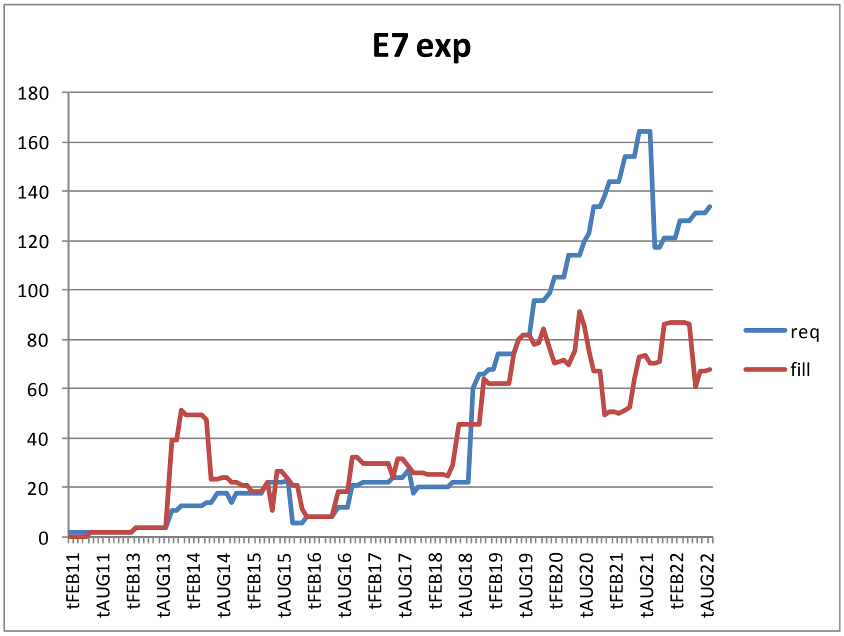

Figure 11. Rank E7 for MOS 6258 shows a significant shortage when accessions are limited to two each month.

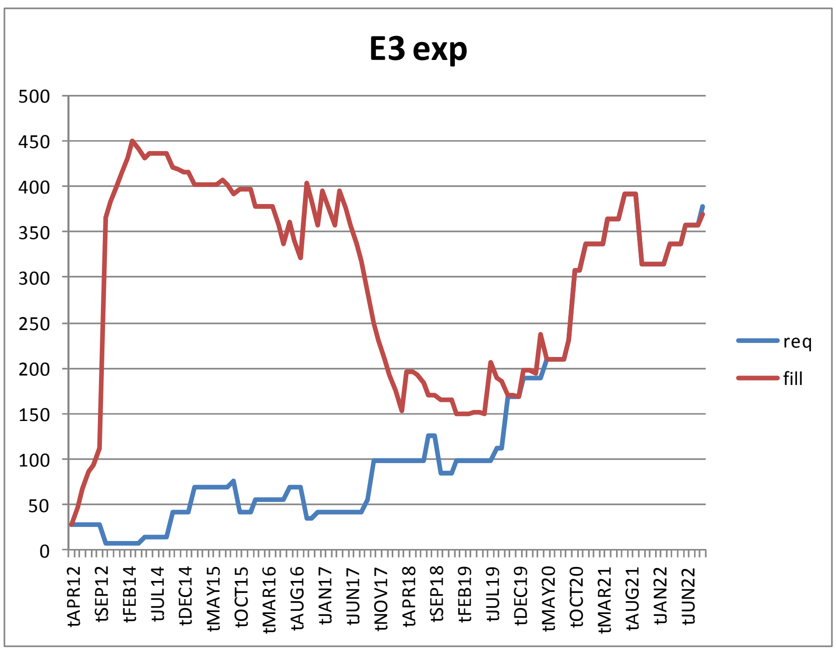

Figure 12. Rank E3 requirements for MOS 6218 are fully satisfied when up to 20 accessions per month are allowed. There is a significant overfill from September 2012 through June 2017. This overfill helps ensure requirements at higher ranks are satisfied during the later years of the planning horizon.

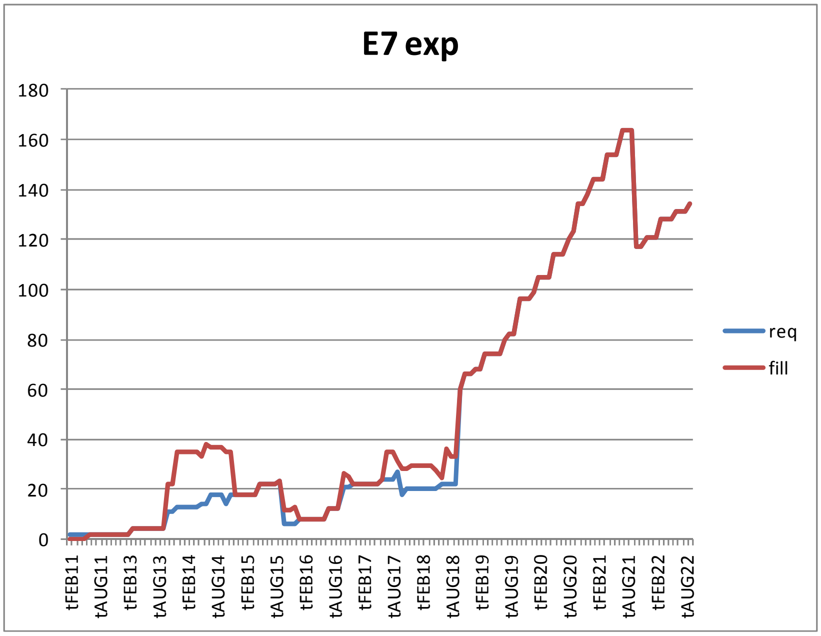

Figure 13. Rank E7 requirements for MOS 6218 are almost exactly satisfied when up to 20 accessions per month are allowed.

V. CONCLUSIONS

This thesis introduces the MCMCAM, a decision support tool to assist the USMC in their JSF integration. The tool uses Integer linear program to prescribe the number of maintenance personnel for transition and accession into the new JSF community. The MCMCAM determines the possible shortage or overfill of manning for each squadron taking into consideration the rank, and Years of Service (YOS) for each month of an 11-year planning horizon. The model considers four separate Military Occupational Specialties (MOS), and enumerates all possible career cycles (possible tours of duty over 11 years) that are available to the maintenance crew. By prescribing a path for each maintainer, MGMCAM captures the long-term implication of each transition and accession. USMC hopes to have the right distribution of maintainers for the new JSF squadrons standup, and their goal to maintain the capability of the legacy aircraft community until they phase out. Using realistic data, we demonstrate use of MGMCAM under different levels of accession and allowed transition for four types of maintenance personnel.

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